III.16 Development of Highly Efficient Solid-State Electrochemical Hydrogen Compressor

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Objectives

- Demonstrate feasibility of a solid-state electrochemical hydrogen compressor (EHC) cell capable of compressing hydrogen from near-atmospheric pressure to up to 6,000 psi.
- Increase the cell performance (reduce power consumption, improve compression efficiency) while lowering the cost compared to previous designs.
- Study thermal and water management to increase system reliability and life.
- Scale up EHC to a short stack.

Technical Barriers

This project addresses the following technical barrier from the Hydrogen Delivery section (3.2) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Reliability and Costs of Hydrogen Compression

Technical Targets

This project is directed at demonstrating the feasibility of solid-state electrochemical hydrogen compression. The EHC is an enabling device for low-cost hydrogen delivery. Phase II goals include the following:

- Compress hydrogen from 300 psi to up to 6,000 psi.
- Develop multi-cell stack design and validate in a short stack.
- Demonstrate compression ratio up to 300:1.
- Achieve stack performance stability at 3,000 psi for 500 hours.
- Increase hydrogen recovery efficiency to 98%.

The ultimate goal of the project is to meet the DOE targets for forecourt compressors [1].

Accomplishments

- Hydrogen Pressure: Reached 6,000 psi hydrogen pressure (single cell).
- Compression Efficiency: Reduced specific energy consumption by >80% compared to the best Phase I result (Figure 1).
- EHC Scale Up: Cell technology scaled up from 3-cell to 10-cell stack.
- Compression Mode Operation: Demonstrated compression ratio of over 300:1 in a single step.
- Operation Hours: 3,000 hr operating time at up to 3,000 psi in single cell, and >500 hr at 3,000 psi in 3-cell stack.
- Hydrogen Recovery: Achieved >98% hydrogen recovery rate in single cells, and 95% in a 10-cell stack.

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Introduction

With the depletion of fossil fuel reserves and a global requirement for the development of a sustainable economy, hydrogen-based energy is becoming increasingly important. Production, purification and compression of hydrogen represent key technical challenges for the implementation of a hydrogen economy, especially in the transportation sector where on-board storage of pure hydrogen may be required at pressures up to 10,000 psi and compression of the hydrogen fuel up to 12,000 psi.

The level of maturity of current hydrogen compressor technology is not adequate to meet projected infrastructure demands. Existing compressors are inefficient and have many moving parts, resulting in significant component wear and therefore excessive maintenance. New technologies that achieve higher operational efficiencies, are low in cost, safe and easy to operate are therefore required. This project addresses

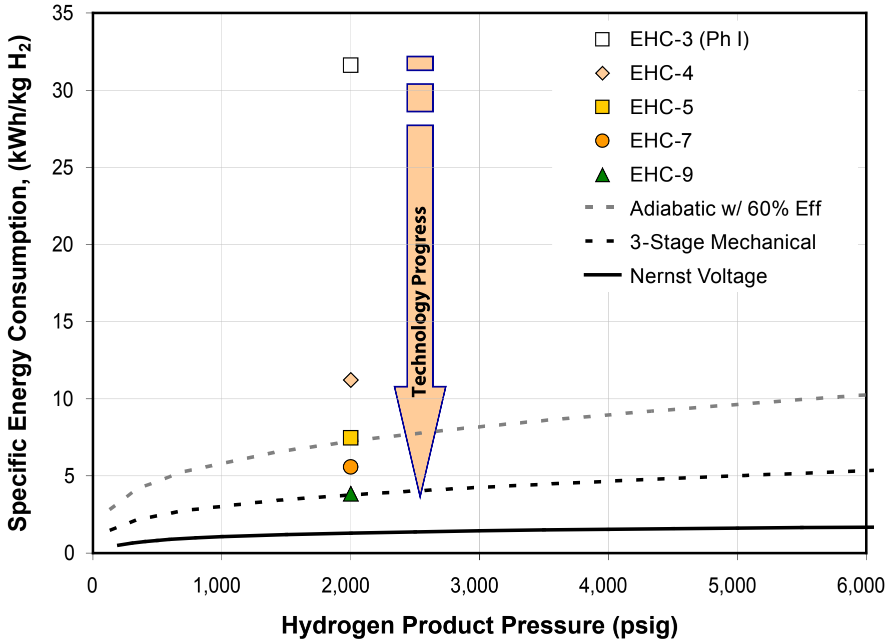

FIGURE 1. Over 80% Reduction in EHC Specific Energy Consumption Achieved

high-pressure hydrogen needs by developing an efficient, low-cost, solid-state EHC.

Approach

The approach to address the Phase II goals consists of the following major elements:

- Build on Phase I experience to develop high-pressure stack design.
- Flow field design to increase hydrogen recovery efficiency.
- Reduce capital cost by reducing catalyst loading and simplifying system design.
- Reduce operating cost by improving membrane and electrode design.

To this end, the approach includes the construction and evaluation of advanced stack architecture, and the development and demonstration of critical sealing technology to contain the high-pressure hydrogen within the cathode compartment of the stack.

Results

The EHC cell architecture has been improved to reduce energy consumption. The specific energy consumption to compress hydrogen from atmospheric pressure to 2,000 psig is 3.8 kWh/kg, as shown in Figure 1. This is a >80% reduction compared to the best Phase I result. The goal of demonstrating a compression ratio of 300:1 has been met. Moreover, in the past year the EHC has been scaled up from a 3-cell stack to a 10-cell stack. It was designed, fabricated and tested at pressures up to 3,000 psi. Hydrogen recovery rates of >98% and 95% have been demonstrated in single cells and a 10-cell stack, respectively.

Conclusions and Future Directions

This project has successfully demonstrated the feasibility of the EHC technology. All major technical targets of this project have been met. They include:

- Compressed hydrogen from near-atmospheric pressure to up to 6,000 psi in a single step without any moving parts.
- Developed multi-cell stack design and validated in a 10-cell stack.
- Demonstrated compression ratio of 300:1.
- Achieved stack performance stability at 3,000 psi for more than 500 hours.
- Demonstrated hydrogen recovery efficiency of >98% in EHC single cells.

This project is ending in Fiscal Year (FY) 2010. Additional work required to further advance the EHC technology includes:

- Improve stack performance to reach 98% hydrogen recovery efficiency.
- Further scale up EHC to increase its capacity to meet demands of near-term applications.
- Further reduce power consumption to approach Nernst equation.

Special Recognitions & Awards

1. This work was awarded the 2009 DOE Hydrogen Program R&D Award during the DOE Hydrogen Program Merit Review and Peer Evaluation Meeting in Washington, D.C.

FY 2010 Publications/Presentations

1. L. Lipp, "Development of Highly Efficient Solid State Electrochemical Hydrogen Compressor (EHC)", 2010 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting, Washington, D.C., June 7, 2010.

References

1. HFCIT MYRDD Plan, Table 3.2.2 "Technical Targets for Hydrogen Delivery", section on Forecourt Compressors, page 3.2-14.